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## Primary research

**Risk factors for hospitalization among adults with asthma: the influence of sociodemographic factors and asthma severity**Mark D Eisner<sup>\*†</sup>, Patricia P Katz<sup>‡</sup>, Edward H Yelin<sup>‡</sup>, Stephen C Shiboski<sup>§</sup> and Paul D Blanc<sup>\*†¶</sup><sup>\*</sup>Division of Occupational and Environmental Medicine, Department of Medicine, University of California, San Francisco, California, USA<sup>†</sup>Division of Pulmonary and Critical Care Medicine, Department of Medicine, University of California, San Francisco, California, USA<sup>‡</sup>Institute for Health Policy Studies, University of California, San Francisco, California, USA<sup>§</sup>Department of Epidemiology and Biostatistics, University of California, San Francisco, California, USA<sup>¶</sup>Cardiovascular Research Institute, University of California, San Francisco, California, USA**Correspondence:** Mark D Eisner MD, MPH, University of California San Francisco, 350 Parnassus Avenue, Suite 609, San Francisco, CA 94117, USA. Tel: +1 415 476 7351; fax: +1 415 476 6426; e-mail: [eisner@itsa.ucsf.edu](mailto:eisner@itsa.ucsf.edu)

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**Abstract****Background:** The morbidity and mortality from asthma have markedly increased since the late 1970s. The hospitalization rate, an important marker of asthma severity, remains substantial.**Methods:** In adults with health care access, we prospectively studied 242 with asthma, aged 18–50 years, recruited from a random sample of allergy and pulmonary physician practices in Northern California to identify risk factors for subsequent hospitalization.**Results:** Thirty-nine subjects (16%) reported hospitalization for asthma during the 18-month follow-up period. On controlling for asthma severity in multiple logistic regression analysis, non-white race (odds ratio [OR], 3.1; 95% confidence interval [CI], 1.1–8.8) and lower income (OR, 1.1 per \$10,000 decrement; 95% CI, 0.9–1.3) were associated with a higher risk of asthma hospitalization. The severity-of-asthma score (OR, 3.4 per 5 points; 95% CI, 1.7–6.8) and recent asthma hospitalization (OR, 8.3; 95% CI, 2.1–33.4) were also related to higher risk, after adjusting for demographic characteristics. Reliance on emergency department services for urgent asthma care was also associated with a greater likelihood of hospitalization (OR, 3.2; 95% CI, 1.0–9.8). In multivariate analysis not controlling for asthma severity, low income was even more strongly related to hospitalization (OR, 1.2 per \$10,000 decrement; 95% CI, 1.02–1.4).**Conclusion:** In adult asthmatics with access to health care, non-white race, low income, and greater asthma severity were associated with a higher risk of hospitalization. Targeted interventions applied to high-risk asthma patients may reduce asthma morbidity and mortality.**Keywords:** asthma, asthma epidemiology, hospitalization**Introduction**

Asthma is a common condition in general medical practice, accounting for about 1% of all ambulatory visits in the USA [1]. The mortality rate from asthma has risen sharply since the late 1970s, which may reflect increasing disease severity [2]. The hospitalization rate, another population-level marker of asthma severity, remains substantial [2],

generating nearly one-half of all US health care costs for asthma [3]. Hospitalization rates for asthma have actually increased in some demographic subgroups, such as young adults [2] and the urban poor [4], despite recent therapeutic advances. Understanding the factors underlying hospitalization for asthma could help elucidate the recent rise in asthma morbidity.

Previous studies have identified several factors that contribute to increased hospitalization risk among adults with asthma. Demographic characteristics, such as poverty, low educational attainment, female gender, and African-American race, have been associated with a greater risk of hospitalization for asthma [2,4–11]. Poor health care access and inadequate preventive asthma care have also been frequently cited as contributing factors [5,12–15]. In these studies, however, separating the independent effects of demographic characteristics, health care access, and disease severity has been difficult. For instance, the association between low income or non-white race and greater asthma hospitalization risk is potentially confounded by inadequate health care access. Because many studies rely on ecologic socioeconomic and hospitalization data, individual-level factors – especially asthma severity – cannot be adequately examined [4–8,15–18]. Other studies have not yet provided prospective follow-up [9,10,19,20] or have not simultaneously considered both demographic and clinical variables [21,22].

In this article, using a prospective cohort study of adults with asthma, we delineate the relative impact of demographic characteristics and asthma severity on subsequent hospitalization for asthma. Since study subjects were recruited from a random sample of physician practices, they all had access to health care for asthma. As a result, we could evaluate the effects of gender, race, income, and asthma severity on hospitalization, independent of health care access.

## Materials and methods

### Subject recruitment and retention

We used data collected during a prospective, longitudinal cohort study of adults with asthma recruited from physician practices in Northern California. Details of the study design have been previously reported [23–26]. Each subject underwent a structured, computer-assisted telephone interview covering demographic characteristics, smoking history, asthma history, symptoms, and treatment, health status, health care utilization for asthma, and insurance for asthma care.

Physicians registered 669 eligible patients. After initial data collection at baseline ( $n = 601$ ) and 18-month follow-up interviews ( $n = 539$ ), we later restricted the data set to 371 of the baseline cohort (55% of total registry) and 242 of the follow-up subjects (65% of restricted baseline cohort). We restricted the data set to eliminate all interviews potentially compromised by faulty data collection or documentation by a single survey interviewer [26,27]. This restricted data set excluded 24 baseline subjects who were found to be outside the study age range and 206 baseline subjects with inconsistent data during subsequent re-interview. Of the 371 baseline subjects, the present study excludes an additional 129 subjects at 18-month

follow-up interview who had inconsistent data at later interviews or did not complete follow-up, leaving 242 follow-up interviews (18 month). These exclusions had no significant effect on study findings.

Demographic data for comparison of the baseline cohort ( $n = 371$ ) with registered subjects ( $n = 669$ ) are not available. Compared with subjects who participated in both baseline and follow-up interviews ( $n = 242$ ), subjects without complete follow-up interviews ( $n = 129$ ) were younger (36.6 years versus 40.5 years) and less likely to have white race/ethnicity (62% versus 71%;  $P < 0.001$  and  $P = 0.10$ , respectively). There were no statistical differences in history of ever smoking (43% of participants in both interviews versus 37% of non-participants at follow-up), female gender (73% versus 66%), atopic history (82% versus 83%), or severity-of-asthma scores (11.0 versus 10.6;  $P > 0.15$  in all cases).

### Hospitalization for asthma

The primary study outcome was self-reported hospitalization for asthma during the 18-month prospective follow-up period. Subjects were asked at 18-month follow-up interviews whether they had been hospitalized for asthma during the previous 18 months. Although subjects could indicate more than one positive response, we analyzed the binary outcome of one or more hospitalization for asthma.

### Risk factor variables

All demographic variables were based on baseline subject interview responses. Current and prior cigarette smoking history was assessed using questions adapted from the National Health Interview Survey [28].

We previously developed and validated a 13-item disease-specific severity-of-asthma score with four subscales: frequency of current asthma symptoms (daytime or nocturnal), use of systemic corticosteroids, use of other asthma medications (besides systemic corticosteroids), and history of hospitalizations and intubations [23–25]. Possible total scores range from 0 to 28, with higher scores reflecting more severe asthma. To examine the relative impact of recent and remote hospitalization on further hospitalization for asthma over longitudinal follow-up, we removed hospitalization from the established severity score and defined two new variables: recent hospitalization (during the 12 months prior to baseline interview), or remote hospitalization (past hospitalization not meeting the previous definition of recent). As a result, the hospitalization and intubation subscale now reflects only prior history of intubation.

Several other clinical aspects of asthma were assessed. We defined asthma onset as the subject-reported age of first asthma symptoms. Atopic history was defined by a reported history of allergic rhinitis or atopic dermatitis.

Because prior work suggests an unexpectedly high prevalence of aspirin intolerance in persons with near fatal asthma [29], we ascertained any history of aspirin sensitivity at baseline interview. Since gastroesophageal reflux disease (GERD) may exacerbate asthma symptoms [30], we evaluated whether subjects were taking H2-blockers or proton pump inhibitors as surrogates for GERD and related conditions. We furthermore determined whether subjects possessed a peak flow meter for home usage.

Generic health status was measured using the Medical Outcomes Study SF-36 questionnaire [31,32]. We assessed several indicators of health care access for asthma care, including whether subjects had a regular site for asthma care, a principal care provider for asthma, medical insurance for outpatient asthma care, and an annual deduction for outpatient medical care. We also identified subjects who appeared to rely on emergency department (ED) services for urgent asthma care. We defined reliance on ED care as one or more self-reported ED visits during the interview interval but no urgent outpatient clinic or office visits for asthma, either to regular or alternate sources of asthma care.

### Statistical analysis

In a previous analysis of pulmonary and allergy specialist care, the severity-of-asthma score was associated with an increased risk of hospitalization at 18-month follow-up [25]. The current study evaluates other risk factors for asthma-related hospitalization, taking baseline asthma severity into account. Because asthma severity may act on the causal pathway between a risk factor and subsequent hospitalization for asthma, we present multivariate models both including and excluding baseline asthma severity and generic health status. For example, low education could increase the risk of hospitalization either directly, through poor self-management strategies, or indirectly, if poorly educated persons have greater asthma severity for other reasons. We also delineate the components of asthma severity – respiratory symptoms, systemic corticosteroid use, other asthma medication use, past intubations, and previous hospitalizations – that are most strongly predictive of subsequent hospitalization.

Interview data were analyzed using SAS 6.12 software (SAS Institute, Cary, NC, USA). We evaluated the association between baseline characteristics and the risk of hospitalization for asthma during the ensuing 18-month follow-up period, reported at the 18-month interview. We use the data set restricted to 242 subjects with verified baseline and follow-up interviews for all analyses.

Bivariate relationships were examined using logistic regression analysis, with separate models for each predictor variable. We used multiple logistic regression analysis to elucidate the independent association between each

baseline variable and the prospective risk of hospitalization. In constructing the multivariate model, all predictor variables whose bivariate odds ratio and 95% confidence interval suggested a possible association with hospitalization were entered into the final model. All variables deemed important on an a priori basis, such as age, were also included.

## Results

### Health care access

Reflecting the sampling method employed, all subjects identified a regular source of asthma care and a primary medical provider for asthma care at baseline interview. The majority of participants (97%) also reported having health insurance covering outpatient visits for asthma. Approximately one-third of subjects indicated having annual insurance deductible for physician visits (31%). The majority of subjects continued to report health insurance coverage (96%) and ongoing primary asthma care (99%) at 18-month follow-up. Despite apparent access to outpatient medical care, a substantial proportion (16%) appeared to rely on the ED for urgent asthma care.

### Demographic factors and the risk of hospitalization: bivariate analysis

Table 1 shows that the mean baseline age was 40.5 years and the majority of subjects were female (73%). A substantial proportion reported ever smoking cigarettes (43%), with fewer indicating current smoking (7%). The majority of subjects indicated white, non-Hispanic race/ethnicity (71%).

Thirty-nine subjects (16%) reported at least one hospitalization for asthma during the prospective 18-month follow-up period. Of the baseline characteristics, non-white race (OR, 2.1; 95% CI, 1.1–4.0) and lower income (OR, 1.3; 95% CI, 1.1–1.5) were associated with a greater risk of hospitalization for asthma during the 18-month follow-up (Table 1). Current smokers had an increased likelihood of hospitalization, although the confidence interval did not exclude no association. Greater educational attainment was related to a lower risk of hospitalization (OR, 0.8 per year of education; 95% CI, 0.70–0.96).

### Clinical risk factors for hospitalization: bivariate analysis

A greater severity-of-asthma score, excluding its hospitalization component, was associated with a higher risk of subsequent hospitalization for asthma (OR, 4.7 per 5-point score increment; 95% CI, 2.9–7.7) (Table 2). Although remote asthma hospitalization did not appear related to risk of ensuing hospitalization, more recent hospitalization was strongly associated with increased risk (OR, 11.6; 95% CI, 5.3–25.2). Other clinical variables that may reflect exacerbating factors, such as aspirin allergy and use of gastric acid suppression medication, were also associated with a greater risk of asthma hospitalization.

**Table 1****Risk factors for hospitalization over longitudinal follow-up: demographic characteristics and smoking**

Risk factor	Baseline interview (mean [SD] or <i>n</i> [%])	Risk of hospitalization at 18 months (OR [95% CI])
Age (per 10 years)	40.5 (7.3)	1.0 (0.6–1.7)
Female gender	177 (73%)	1.1 (0.5–2.4)
Non-white race/ethnicity	71 (29%)	2.1 (1.1–4.0)
Education (years)	14.9 (2.5)	0.8 (0.70–0.96)
Household income*	45,000	1.3 (1.1–1.5)
Married or cohabitating	160 (66%)	1.0 (0.5–2.1)
Current cigarette smoking	18 (7%)	2.1 (0.7–6.4)
Past cigarette smoking	87 (36%)	1.3 (0.6–2.6)

Bivariate analysis (*n* = 242). \*Median household income (25th–75th interquartile range, \$25,000–\$62,500); odds ratio per \$10,000 decrement.

Better baseline generic physical health status (SF-36) was associated with a slightly decreased risk of subsequent hospitalization (6% reduction in odds per 1 point score increment; 95% CI, 3–9%) (Table 2). Mental health status was furthermore associated with a 4% reduction in the risk of hospitalization per 1 point (95% CI, 0–7%). Reliance on emergency department care was finally related to a greater risk of hospitalization (OR, 2.5; 95% CI, 1.1–5.5).

**Table 2****Risk factors for hospitalization over longitudinal follow-up: clinical factors, asthma severity, health status, and health care access**

Risk factor	Baseline interview (mean [SD] or <i>n</i> [%])	Risk of hospitalization at 18 months (OR [95% CI])
<b>Asthma severity</b>		
Severity-of-asthma score (per 5 points)	11.1 (4.8)	4.7 (2.9–7.7)
Recent hospitalizations for asthma*	60 (25%)	11.6 (5.3–25.2)
Remote hospitalizations for asthma†	64 (26%)	0.7 (0.3–1.6)
<b>Other asthma clinical factors</b>		
Childhood onset (before 18 years)	117 (48%)	1.0 (0.5–2.0)
Atopic history	199 (82%)	0.5 (0.2–1.1)
Aspirin allergy history	32 (13%)	2.3 (1.0–5.6)
Gastric acid suppression medication (in prior 12 months)	62 (26%)	2.7 (1.3–5.5)
<b>Generic health status</b>		
SF-36 Physical component score (per 1 point)	43.1 (12.0)	0.94 (0.91–0.97)
SF-36 Mental component score (per 1 point)	44.3 (9.2)	0.96 (0.93–1.0)
<b>Health care access</b>		
Deductable for physician office visits	76 (31%)	1.0 (0.5–2.0)
Reliance on ED for urgent asthma care	39 (16%)	2.5 (1.1–5.5)

Bivariate analysis (*n* = 242). ED, emergency department. \*Recent hospitalizations, hospitalization during 12 months prior to baseline interview or 18 months prior to 18-month follow-up interview. †Remote hospitalizations, hospitalization more than 12 months prior to baseline interview.

**Risk of hospitalization – multivariate analysis**

We examined the independent impact of selected covariates on the prospective risk of hospitalization for asthma using multiple logistic regression analysis (Table 3). Of the demographic characteristics, non-white race was associated with a greater risk of subsequent asthma hospitalization (OR, 3.1; 95% CI, 1.1–8.8) after controlling for asthma severity and the other covariates shown. Lower household income was also related to a greater risk of hospitalization (OR 1.1 per \$10,000 decrement), although the 95% confidence interval did not exclude no relation to hospitalization (0.9–1.3). Controlling for demographic and other variables, greater severity-of-asthma score (OR, 3.4 per 5-point increment; 95% CI, 1.7–6.8) and recent hospitalization for asthma (OR, 8.3; 95% CI, 2.1–33.4) were strongly associated with an increased risk of hospitalization. Reliance on ED for urgent asthma care was also related to greater risk.

We examined the relation between race and hospitalization in more detail. African-American race was associated with an increased risk of hospitalization for asthma, compared with white, non-Hispanic persons, after controlling for covariates (OR, 10.2; 95% CI, 1.8–58.4). Hispanic race/ethnicity also appeared related to hospitalization (OR, 4.0; 95% CI, 0.9–18.0). There was no apparent relation between Asian race and risk of hospital admission (OR, 2.0; 95% CI, 0.4–10.9).

To further examine the association between asthma severity and hospitalization, we repeated the multivariate analysis dividing the overall severity-of-asthma score into its

**Table 3****Risk factors for hospitalization at 18-month longitudinal follow-up**

Risk factor	Adjusted for all variables shown (OR [95% CI])	Adjusted for all variables, except asthma severity and health status (OR [95% CI])
Demographic characteristics and smoking		
Age (per 10 years)	1.2 (0.7–2.4)	1.2 (0.7–2.1)
Female gender	1.5 (0.5–4.6)	1.2 (0.5–2.8)
Non-white race (non-Hispanic)	3.1 (1.1–8.8)	1.9 (0.9–4.3)
Education (years)	0.8 (0.6–1.1)	0.9 (0.7–1.1)
Household income (per \$10,000 decrement)	1.1 (0.9–1.3)	1.2 (1.02–1.4)
Current cigarette smoking	1.4 (0.2–7.9)	1.2 (0.3–4.6)
Past cigarette smoking	0.7 (0.2–2.0)	1.4 (0.6–3.3)
Asthma severity		
Severity-of-asthma score (per 5 points)	3.4 (1.7–6.8)	N/A
Recent hospitalizations for asthma	8.3 (2.1–33.4)	N/A
Remote hospitalizations for asthma	2.7 (0.6–11.5)	N/A
Other asthma clinical factors		
Atopic history	0.7 (0.2–2.3)	0.5 (0.2–1.4)
Aspirin allergy history	0.7 (0.2–2.3)	1.7 (0.6–4.6)
Gastric acid suppression medication (in prior 12 months)	0.7 (0.2–2.0)	2.2 (1.0–4.9)
Health status		
SF-36 Physical component score	0.98 (0.94–1.03)	N/A
SF-36 Mental component score	0.97 (0.92–1.02)	N/A
Health care access		
Reliance on ED for urgent care	3.2 (1.0–9.8)	2.3 (1.0–5.7)

Multivariate analysis ( $n = 242$ ). ED, emergency department; N/A, not applicable.

four subscales. The systemic corticosteroid score (OR, 1.7 per 5-point score increment; 95% CI, 1.3–2.3) and recent hospitalization for asthma (OR, 9.7; 95% CI, 2.2–43.0) were significantly associated with an increased risk of asthma hospitalization, after controlling for covariates. There was, conversely, no statistical relationship between other asthma medications (OR, 1.1; 95% CI, 0.8–1.6) or asthma symptom scores (OR, 1.2; 95% CI, 0.7–1.9) and the ensuing risk of hospitalization. Systemic corticosteroid use and recent asthma hospitalization, then, appear to drive the relationship between asthma severity and hospitalization for asthma.

Because asthma severity could act as a causal intermediate between a risk factor and the risk of hospitalization, we repeated the multivariate analysis excluding asthma severity and generic health status from the model (Table 3). In this analysis, low income was more strongly related to a greater risk of hospitalization for asthma (OR, 1.2; 95% CI, 1.02–1.4). Use of gastric acid suppression therapy was also associated with increased risk (OR, 2.2; 95% CI, 1.0–4.9). Although other point estimates and confidence intervals changed slightly, there were no other notable changes compared with the model controlling for asthma severity.

To examine whether subjects without baseline health insurance coverage (3%) were affecting study results, we repeated the multivariate analysis excluding these subjects. Only one of the 39 subjects hospitalized at follow-up had no baseline health insurance. There was no meaningful impact on the results in all multivariate analyses. For example, the estimate for lower income in the model without asthma severity was nearly unchanged (OR, 1.2; 95% CI, 1.03–1.4).

## Discussion

Asthma-related morbidity and mortality have risen sharply in the USA since the late 1970s [2]. Hospitalization for asthma, a potentially avoidable outcome, is an important population-level marker of asthma severity. In this prospective study of adults with continued access to medical care for asthma, we identified two demographic factors (low income and non-white race) that were associated with a greater risk of hospitalization for asthma. Reliance on the emergency department for urgent asthma care was also associated with a greater risk of subsequent hospitalization. Greater asthma severity, as indicated by recent asthma hospitalization and systemic corticosteroid use, was related to an increased likelihood of hospitalization.



Ecologic studies, based on US census data, have demonstrated a strong inverse relationship between median household income and hospitalization rates for asthma [4–6,15,16]. Adults with asthma who live in lower income geographic regions have higher rates of asthma hospitalization, even after accounting for race and urbanicity [5]. Investigators have also observed a similar association between community income level and mortality from adult asthma [33–35]. Since these studies lack individual-level income data, investigators have urged cautious interpretation [6]. The present study, using individual level data, supports the association between lower household income and a greater risk of hospitalization. The relationship between lower income and hospitalization is less strong in the model including asthma severity and health status, suggesting that greater asthma severity may mediate this association.

The relationship between low income and asthma hospitalization has many potential explanations, including inadequate health care access. Low income persons in a population-based survey were approximately three times more likely to report difficulty paying for physician bills or prescription drugs than those persons with higher income [36]. Among adults hospitalized for asthma at a single institution, nearly one-third of low income subjects indicated no usual source of outpatient asthma care at 3-month follow-up [14]. In the present study, however, nearly all subjects reported health insurance and access to ambulatory care for asthma, making this an unlikely explanation. Moreover, excluding subjects without baseline health insurance coverage had no appreciable effect on the results.

Beyond health care access, the process of asthma care may be less adequate among low income persons. Haas *et al* found that, after admission to the hospital for asthma, low income patients received lower intensity asthma management than those patients with higher income [14]. Another study demonstrated an association between a surrogate marker of low income (unemployment) and high daily beta agonist use [20], which is an established risk factor for asthma hospitalization [37]. In a managed care setting, which should ensure health care access, low income asthma patients were less likely to visit an asthma specialist [10]. Low income may alternatively be a marker for other exacerbating factors, such as cockroach antigen exposure [6,38], cigarette smoking, secondhand smoke exposure [39], or viral upper respiratory infections.

African-American race has been associated with higher hospitalization rates for asthma in both population-based [2] and ecologic studies [4–7,15,16]. Socioeconomic status and health care access, however, may confound the relationship between race and hospitalization. Several small-area analyses found higher asthma hospitalizations rates among African-Americans, after statistically controlling for income [4,5,15]. Other analyses have found no

effect of race, after taking income into account [11]. In children with access to health care through Medicaid, investigators still observed higher hospitalization rates for African-Americans with asthma [13]. African-American asthma patients similarly had a greater risk of hospitalization for asthma in managed care settings with access to primary care [10,20]. Even after taking insurance status into account, a national survey found a higher proportion of African-Americans reporting difficulty affording medical care than that of whites [36]. Our study suggests that the increased risk of hospitalization for asthma among African-Americans is not entirely explained by income, education, or health care access, which were controlled by design or analysis.

We also discovered a suggestion that persons of Hispanic race or ethnicity had a higher risk of hospitalization for asthma compared with white, non-Hispanic adults. Previous studies focusing on Hispanic persons have provided inconsistent findings. Studies from New York City and Boston indicate that Hispanic persons are hospitalized more frequently for asthma [4,6], whereas previous data from California have not found an increased risk [5]. Other studies have demonstrated a decreased morbidity and mortality from asthma among Hispanic adults [40–42]. The heterogeneity of persons of Hispanic race or ethnicity may explain these variable results.

Higher severity-of-asthma scores were associated with a greater risk of hospitalization for asthma. On examining disease-specific severity in more detail, we found that recent asthma hospitalizations and systemic corticosteroid use accounted for most of this increased risk, whereas recent respiratory symptoms and other asthma medication use were not predictive. In a recent analysis of adult health maintenance organization members with asthma, systemic steroid use and previous hospitalization were also associated with greater risk of hospitalization [21]. A study of hospitalized asthma patients similarly found that both factors were related to rehospitalization [43]. Neither study, however, controlled for sociodemographic characteristics, such as low income, that are associated with hospitalization risk. In the present study, disease-specific severity was associated with a greater risk of hospitalization, controlling for other demographic, clinical, and health care access factors.

Our findings differ from previous studies that found female gender and current smoking as risk factors for asthma hospitalization [9,39]. Female gender has not consistently been related to hospitalization for asthma [44]. The lack of association with smoking could be explained by the 'healthy smoker effect' [45]. According to this principle, persons who develop smoking-related respiratory symptoms quit smoking, resulting in current smokers who are less susceptible to acute effects of smoking.

Previous studies evaluating the effect of GERD on asthma morbidity have provided mixed results [46,47]. In the present study, use of gastric acid suppression therapy, a potential surrogate for GERD, was associated with a greater risk of asthma hospitalization only in multivariate analysis that did not control for asthma severity. This suggests that increased asthma severity may function as a causal intermediate between GERD (or related conditions) and the increased likelihood of hospitalization for asthma. Consistent with this finding, Levin *et al* found that treatment of GERD with omeprazole improved asthma-specific quality of life [30].

Because adults with asthma treated by specialists usually have more severe asthma than those treated by generalist physicians [25], our study results should be generalized to the overall population of asthmatic persons with caution. Although our sampling method attenuates confounding by access to medical care for asthma, the results may not fully apply to populations without health care access. Also reflecting the sampling from specialty practices, study subjects had a higher median household income and educational attainment than the general population. Even so, low income was a risk factor for asthma hospitalization, suggesting that our findings may be more broadly applicable.

The present study has additional limitations, including the reliance on self-reported health care utilization. Socioeconomic differences in recall or reporting of hospitalization, for instance, could influence the risk model. Although we were able to simultaneously consider demographic, clinical, and severity-related covariates, the current study does not fully elucidate the causal intermediates between predictors (eg income or race) and the risk of hospitalization. Finally, our use of self-reported health insurance status and source of regular asthma care may not fully ascertain other, more subtle, barriers to effective asthma care. Previous work has demonstrated that health insurance status does not fully explain health care-related financial problems [36]. Transportation difficulties, work-related demands, and regional differences in health care quality may also have impeded access to efficacious asthma care. Despite these limitations, we believe the present study results may be generalized to persons with moderate to severe asthma.

## Conclusion

Although the morbidity and mortality from asthma are increasing in the USA and around the world, the minority of adults with asthma will experience hospitalization or death from asthma. Targeted interventions could potentially benefit high-risk individuals in a cost-effective manner. Our results suggest that simple demographic and clinical features, especially low income, non-white race, previous hospitalization history, systemic corticosteroid use, and reliance on emergency department for urgent

asthma care, can identify such high-risk patients for more intensive therapy.

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## Supplementary material

### Subject recruitment and retention

In brief, we recruited a random sample of certified American Board of Medical Specialty pulmonary specialists and allergy/immunology specialists. The participating physicians maintained a registry of persons aged 18-50 years with outpatient visits for asthma over a prospective 4-week period. Each person registered by a participating physician was contacted to arrange a telephone interview.

### Risk factor variables

We ascertained household income as a series of increments (less than \$5000, \$5001-\$10,000, \$10,000 increments up to \$50,000, \$50,001-\$75,000, and above \$75,000). To convert to specific income levels, the mid-increment value was applied (except for the highest category, where we used a value of \$87,500).

The severity-of-asthma score systemic corticosteroid subscale includes items for any past corticosteroid use, use during the past 12 months, and steroid dependency. The asthma medication subscale incorporates current use of inhaled corticosteroids, inhaled non-steroidal anti-inflammatory agents, inhaled bronchodilators, oral beta agonists and theophylline-containing medications, nasal medications (antihistamines, decongestants, and topical corticosteroids), and home nebulizer use. In this subscale, one point is assigned for each medication used during the past 2 weeks, with one additional point for frequent inhaled beta agonist or corticosteroid use.

We measured generic health status using the Medical Outcomes Study SF-36 questionnaire. Previous work demonstrates the SF-36 instrument's validity in adult asthma [31]. The physical and mental component summary scores have been defined from the eight SF-36 subscales by factor analysis [32], which measure physical and mental dimensions of health, respectively. Each summary score in the general US population has a mean of 50 and a standard deviation of 10. Higher scores reflect more favorable health states.